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A Detailed Emission Inventory of Sulphur Dioxide for Denmark

Risø-M-2937(EN)

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Abstract. The Danish SO₂ emissions from domestic heating, energy generation, industry, road traffic, point sources and maritime vessels have been distributed on a 1 × 1 km² grid and on municipalities.

The total SO₂ emission is calculated to 351 Ktonne SO₂ a⁻¹. This report describes the distribution, of the emissions from the different categories on the grid and municipalities.

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Summary

The emissions of SO_2 in Denmark from domestic heating, energy generation, industrial combustion, industrial production, road traffic, large point sources and some maritime vessels have been computed and distributed on a grid with $1 \times 1 \text{ km}^2$ elements. The land based area sources have also been distributed among municipalities.

Emission data from the EEC database Corinair for Denmark have been used for domestic heating, energy generation, industrial combustion, industrial production and road traffic. For freighters and ferries, emissions proposed by the European Monitoring and Evaluation Program (EMEP) and information from the Danish State Railways (DSB), have been used to calculate the emissions.

The distribution of the emissions from area sources on land over the $1 \times 1 \text{ km}^2$ grid has been performed using statistics on the total number of inhabitants in each municipality, inhabitants in urban areas and the registration of the land use by Runge and Asman (1989). For road traffic, the emissions have, for major roads been distributed, using information from the Road Data Laboratory (Vejdatalaboratoriet) on placement of the roads in the country. On minor roads, the emissions have as for other area sources on land, been distributed according to the number of inhabitants. Further, the distribution of emissions among municipalities has been done using both the grid and the land use registrations.

The total Danish SO_2 emission, is estimated to be $351 \text{ Ktonne SO}_2 \text{ a}^{-1}$.

Sammenfatning

Emissionen af SO_2 i Danmark fra boligopvarmning, energiproduktion, industriel forbrænding, industriel produktion, vejtrafik, punktkilder samt nogle skibs- og færgeruter er opgjort og fordelt på et $1 \times 1 \text{ km}^2$ net. Areakilderne på land, er desuden fordelt på kommuner.

For boligopvarmning, energi produktion, industriel forbrænding, industriel produktion og vejtrafik er brugt data fra EF-databasen Corinair, for Danmark. For skibs- og færgeruter er brugt emissionsstørrelser, som er foreslået af EMEP (European Monitoring and Evaluation Program) og information fra DSB, i beregningen af emissionen.

Fordelingen af emissionen fra arealkilder på land, over $1 \times 1 \text{ km}^2$ nettet er foretaget ud fra befolkningstallene i de enkelte kommuner totalt og i byområder samt ud fra registreringen af arealets anvendelse som opgjort i 'Land-use' registreringen (Runge og Asman, 1989) For vejtrafik er emissionen på de større veje fordelt ud fra information fra Vejdatalaboratoriet, om vejenes placering i landet. På de mindre veje er emissionen fordelt, som for de andre arealkilder på land, efter befolkningstætheden.

Ud fra opgørelsen af emissionerne på $1 \times 1 \text{ km}^2$ er, ved hjælp af registreringen i 'Land-use' af hvilke kommuner hver enkelt km^2 ligger i, beregnet emissionens fordeling på kommuner.

Den samlede danske SO_2 emission beregnet til $351 \text{ Ktons SO}_2 \text{ år}^{-1}$.

1 Introduction

One of the important components in acidification of the environment is sulphur. To be able to model the dispersion and deposition of sulphur components in Denmark, a detailed emission inventory is necessary. The present report describes the characteristics of such a detailed emission inventory for SO₂.

A SO₂ emission inventory for Denmark anno 1985 had already been made by the System Analysis Department of Risø National Laboratory, Roskilde, Denmark, within the framework of the EEC Corinair project. This emission inventory consists of two parts: detailed information on the emissions from large point sources and information on emissions from area sources for each county («amt» in Danish). The latter information, however, is not detailed enough to be used for modelling gradients over Denmark. It was therefore decided to make a more detailed emission inventory for area sources, partly by using information from the existing inventory on domestic heating, energy generation, road traffic and industrial sources. These emissions were then distributed among municipalities («kommuner» in Danish) and on a grid with 1 × 1 km² elements applying the land-use database for Denmark, developed at NERI (Runge and Asman, 1989). Emissions from maritime vessels were computed separately using data from the Danish State Railways (DSB).

The grid used in this inventory is the Universal Transverse Mercator (UTM) grid (Geodætisk Institut, 1981). The UTM grid is divided into zones. Most of Denmark is situated in Zone 32, but the eastern part of Zealand and Bornholm are situated in Zone 33. To make the inventory more uniform, the Zone 33 coordinates of Zealand and Bornholm, have been transformed to Zone 32 coordinates. That is, all coordinates in the inventory are given in UTM Zone 32.

Risø National Laboratory computed the emission from domestic heating, energy generation, road traffic and industrial production and combustion.

Erik Runge at NERI performed the computations of emissions from maritime vessels, the distribution of SO₂ emissions among municipalities and grid elements and the construction of the detailed inventory.

The computation of emissions have been done using in principle the same programs as used in Runge, Asman and Kilde (1991).

2 Emissions from area sources on land

2.1 Introduction

The following categories of SO₂ emissions from area sources have been taken from the Corinair database:

- domestic heating
- energy generation
- industrial combustion
- industrial production
- road traffic.

The difference between emissions from industrial combustion and those from industrial production is that in combustion, the flue gases are not in direct contact with the produced material, whereas in production they are.

2.2 Computation of the gridded emissions

In the Corinair database the total emission from domestic heating, energy generation, industrial combustion, industrial production and road traffic, for each county is given. For use in dispersion models, we wanted to have the emissions on a regular grid. Therefore the Corinair data were distributed on a 1×1 km² grid.

But as dispersion models using a 1×1 km² grid may be considered to be unnecessarily time consuming, the emissions were additionally distributed on a 5×5 km² grid.

Within each county and municipality the emissions were distributed according to the land-use registration of Runge and Asman (1989), where for each km² it has been registered i.a. how much of the area is urban and how much is farmland.

It was assumed that all industry and energy generation is placed in urban areas. The total emission from industry and energy generation was distributed evenly over all areas which have been registered as urban. The emissions from domestic heating were for each municipality, within the urban areas distributed according to the number of inhabitants in urban areas, while in other areas they were distributed evenly according to the total number of inhabitants not living in urban areas. The distribution on the 1×1 km² grid was conducted using again the land-use registration.

The emissions from the road traffic have also been distributed on the 1×1 km² grid. From the Danish Road Data Laboratory (RDL) («Vejdatalaboratoriet» in Danish) under the Road Directorate, we have received information on the positions of all Danish state and county roads, i.e. all major roads in Denmark (S. Schrøder, RDL, pers. comm. 1990). Each road was divided into smaller pieces. To each piece were attached i.a. the road number, the coordinates of the beginning and ending points and the yearly traffic.

Using questionnaires the RDL has estimated the total traffic per year on all Danish roads. By subtracting the sum of the traffic on main roads from the total traffic, we obtained an estimate of the traffic on minor (mainly municipal) roads in Denmark.

As we for most of the major roads have their placement in the country by their beginning and ending coordinates for each road piece, they have in this way been distributed on the 1×1 km² grid net. For road pieces where coordinates of the beginning and ending points were missing, the emissions were distributed evenly over the county in which the road is situated (this was the case for county roads in Ringkøbing amt).

The emissions on minor roads have been distributed over the municipalities according to the number of inhabitants in each municipality (1988 statistics given by the Danish Statistical Office). Within municipalities the emissions have been distributed on the 1×1 km² grid, using information in the land-use registration and population data from the Danish Statistical Office. We have, using this distribution key, assumed that all inhabitants in Denmark drive equally much on municipal roads.

Thus all land based SO₂ area emissions were computed and distributed on a 1×1 km² grid. The data were stored in a data file named SO2AREA.dat. The distribution of emissions over municipalities was done using the file SO2AREA.dat and the land-use registration, the latter in which each km² is subordinated to municipalities. The results of this distribution are shown in Table 1.

Figures 1 to 5 show the geographical distribution of the SO₂ emissions for the five different categories; domestic heating, energy generation, industrial combustion, industrial production and traffic. Figure 6 shows the geographical distribution of the total SO₂ emission from area sources in Denmark.

3 Emissions from large point sources on land

3.1 Introduction

The following categorizing of SO₂ emission point sources have been taken from the Corinair database:

- power stations over 300 MW
- oil refineries
- manufacturing of sulphuric and nitric acid
- iron- and steelworks
- paper mills
- car lacquering works with over 100000 cars a⁻¹.

Of these categories it is mainly major power stations which in Denmark are categorized as point sources. Sources, in Denmark, which are too small to be categorized as a point source are registered in the Corinair database for area sources.

3.2 Locations of the emissions

In the Corinair database the location of a point source is given by its global longitude and latitude. These have been transformed to UTM Zone 32 coordinates.

In Table 2, are listed the total SO₂ emissions from major point sources for the counties in Denmark. In Figure 7 are plotted the major point sources. Note that the diameter of a circle in the figure shows the relative magnitude of the corresponding source or cluster of sources.

4 Emissions from maritime vessels

4.1 Introduction

The emissions from maritime vessels can be divided into different categories, such as:

- international freighter traffic
- national freighter traffic
- international ferry traffic
- national ferry traffic
- fishing boats
- leisure vessels
- military ships
- other maritime vessels.

In this study only emissions from international freighter traffic and some of the main national ferries were included.

Of importance for the SO₂ emissions are especially for ferries the time used in port and the time used for arrival at and departure from ports. Which have not been taken into account in this investigation.

4.2 SO₂ emissions from international freighter traffic

There are two main routes for international freighter traffic through Danish waters. These are (see Figure 8):

Route T from Skagen, east of the island of Anholt, through the Great Belt (Storebælt), south of Lolland and Falster and into the Baltic Sea (Østersøen).

Route D/B which is initially as route T, but from Anholt it goes southeast through the Sound into the Baltic Sea.

North of Skagen and within the Baltic Sea the ships do not follow specific routes but sail in different directions depending on their destinations. For this reason, the SO₂ emissions have been estimated and gridded only for those route sections as shown in Figure 8.

There are other freighter routes in Danish national waters, but these two are the most important.

The total emission was calculated using the emissions given by Bremnes (1990). For route T from Skagen to southeast of Lolland, Bremnes gives an emission of 31 tonne SO₂ per nautical mile per year (tonne nmi⁻¹ a⁻¹).

Southeast of London a different route passing through the Kiel Canal joins route T, and the emission from the joining point further eastwards is 78 tonne nmi⁻¹ a⁻¹. Along route D/B the emission is 19 tonne nmi⁻¹ a⁻¹. These emissions must be taken as average emissions for all types of freighters.

4.3 SO₂ emissions from national ferry services

The ferry services in Denmark are run by different companies, of which the largest are DSB, DFDS and Bornholmstrafikken. Of these, DSB is by far the largest, having 29 ferry routes. We were given information on the 9 most important DSB routes, including their yearly consumption of marine dieseloil and fueloil. The 9 routes are shown in Figure 9.

The SO₂ emissions were calculated on the basis of the oil consumption, and information from DSB, that the sulphur content of the marine dieseloil is less than 1.0% whereas the sulphur content of fueloil varies between 2.3 and 2.9%. The yearly oil consumption was given in m³. As the density of the fuel used varied between 0.80 and 0.95 tonne m⁻³, a mean density of 0.85 tonne m⁻³ was used. In the calculations we assume a sulphur content of 1% in marine dieseloil and uses the percent sulphur content in fueloil as given by DSB on the actual routes. We also assume, that all of the sulphur is emitted as SO₂.

For each of the 9 routes the emission was calculated and distributed evenly along the route (thus not taking into account the time the ferries spent in port or navigating in and out of ports).

4.4 Computation of the gridded emissions

The estimated SO₂ emissions from international freighter traffic and main ferry services are shown in Table 3.

The emissions from international freighter traffic as distributed on the UTM grid are shown in Figure 10. The gridded emissions from main ferry services are shown in Figure 11.

5 Total emissions

The total Danish SO₂ emission comprising all major point and area sources over land and sea, as estimated in this survey, adds up to approximately

351 Ktonne SO₂ a⁻¹.

In Table 4 are listed the total SO₂ emissions from the different source categories in this survey, and in Figure 12 these are visualised in a pie chart.

6 Comparison with other emission estimates and uncertainties in the inventory

6.1 Comparison with other emission estimates

Some SO₂ emission inventories for Denmark have been made for various source categories, prior to the present inventory, but as there have been no standards within this field of work, comparison between inventories is difficult.

For the total emission from road traffic, Torp (1983) has made an inventory for the year 1980 in which this emission is estimated to be

15 Ktonne SO₂ a⁻¹.

In the present survey, the road traffic emission is estimated to be

11 Ktonne SO₂ a⁻¹.

The total SO₂ emission from point and area sources, but not including emissions from maritime vessels, has been calculated by Torp (1983) to be in 1980

417 Ktonne SO₂ a⁻¹.

If in the present survey the total emissions from area sources and large point sources are added together, we get an emission in 1985 of

334 Ktonne SO₂ a⁻¹.

which is 25% lower than the figure given by Torp. The difference is partly due to a reduction in energy consumption and partly due to a change from use of oil to use of coal in the power plants. The reduction is not due to a regulation in the sulphur content of the fuel, which was first prescribed by law after 1985.

Another estimate of the total SO₂ emissions in 1985, given by N. Halvorsen (EMEP, Pers. comm., 1990), is

340 Ktonne SO₂ a⁻¹.

It is seen that there is a reasonable agreement between the total emissions given in the different inventories.

6.2 Uncertainties in the inventory

It is estimated that there are uncertainties of the order of 10% in much of the SO₂ emissions data in the Corinair database.

The distribution of area sources over municipalities has in the present study been done according to the number of inhabitants in each municipality. Other distribution keys could have been used, e.g. for traffic or for

domestic heating and energy generation. Which would lead to different results. Thus the resulting distribution, as listed in Table 1, should be treated with caution.

The uncertainty in the estimate of the total emission from maritime vessels is very large, mainly because a great number of lesser transport were omitted. The real total emission from maritime vessels could well be twice as high.

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Tables

Note that in several of the tables, the SO₂ emissions are listed with greater accuracy than warranted by the uncertainties in the present investigation.

Table 1. SO₂ emissions for different source categories and emission densities for each municipality and county in Denmark. Only area sources are listed in this table. Point sources are for each county listed in Table 2.

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|--------------------------------|---|----------------------|--------------------------|--------------------------|-----------------|---------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | Road traffic | | |
| 101 | København | 3132.4 | 1697.8 | 5823.8 | 653.8 | 437.3 | 11745.1 | 133.3 |
| 147 | Frederiksberg | 541.6 | 285.4 | 1006.9 | 113.0 | 69.4 | 2016.3 | 229.9 |
| 013 | København and Frederiksberg | 3673.9 | 1983.1 | 6830.7 | 766.8 | 506.7 | 13761.4 | 142.0 |

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|---------------------------|---|----------------------|--------------------------|--------------------------|-----------------|---------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | Road traffic | | |
| 151 | Ballerup | 309.1 | 419.0 | 574.5 | 64.7 | 92.6 | 1459.9 | 42.8 |
| 153 | Brøndby | 233.9 | 317.1 | 434.7 | 48.8 | 112.9 | 1147.3 | 55.4 |
| 155 | Dragør | 83.7 | 113.5 | 155.6 | 17.5 | 16.9 | 387.2 | 21.4 |
| 157 | Gentofte | 461.8 | 594.8 | 858.4 | 96.4 | 120.6 | 2132.0 | 83.5 |
| 159 | Gladsø | 419.8 | 553.5 | 780.2 | 87.6 | 144.7 | 1985.8 | 79.4 |
| 161 | Glostrup | 139.7 | 189.4 | 259.7 | 29.2 | 62.9 | 680.8 | 51.2 |
| 163 | Herlev | 182.0 | 244.4 | 338.3 | 38.0 | 52.5 | 855.2 | 71.0 |
| 165 | Albertslund | 192.6 | 261.1 | 357.9 | 40.2 | 63.9 | 915.7 | 39.7 |
| 167 | Hvidovre | 336.5 | 443.6 | 625.5 | 70.2 | 95.1 | 1570.9 | 72.5 |
| 169 | Høje Tåstrup | 298.1 | 403.5 | 553.1 | 62.1 | 131.2 | 1448.0 | 18.2 |
| 171 | Ledøje-Smørum | 59.6 | 80.6 | 110.5 | 12.4 | 11.8 | 274.8 | 8.8 |
| 173 | Lyngby-Tårnby | 329.5 | 446.9 | 612.5 | 68.8 | 100.5 | 1558.2 | 40.0 |
| 175 | Rødovre | 246.7 | 317.6 | 458.5 | 51.5 | 81.5 | 1155.8 | 95.4 |
| 181 | Søllerød | 212.5 | 287.2 | 396.1 | 46.2 | 74.8 | 1016.8 | 25.6 |
| 183 | Ishøj | 137.1 | 185.7 | 255.1 | 28.6 | 62.0 | 668.5 | 27.0 |
| 185 | Tårnby | 284.9 | 358.5 | 529.5 | 59.5 | 57.1 | 1289.5 | 20.6 |
| 187 | Vallensbæk | 80.0 | 108.5 | 148.7 | 16.7 | 41.3 | 395.2 | 43.0 |
| 189 | Værløse | 122.4 | 165.8 | 227.3 | 25.5 | 44.1 | 585.2 | 17.2 |
| 015 | Københavns amtskommune | 4130.0 | 5490.7 | 7676.2 | 863.8 | 1366.4 | 19527.0 | 37.1 |

Continued

Table 1 continued

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|------------------------------|---|----------------------|--------------------------|--------------------------|---------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | | |
| 201 | Allerød | 133.3 | 159.1 | 271.9 | 67.5 | 631.8 | 10.2 |
| 205 | Birkeroed | 133.5 | 160.6 | 271.8 | 66.0 | 631.9 | 20.6 |
| 207 | Farum | 103.5 | 123.9 | 211.7 | 52.5 | 591.6 | 23.4 |
| 208 | Fr. borg-Humlebaek | 116.1 | 138.6 | 236.9 | 58.8 | 550.4 | 8.3 |
| 209 | Frederikssund | 103.0 | 123.7 | 211.0 | 52.0 | 589.7 | 12.8 |
| 211 | Frederiksværk | 109.8 | 132.0 | 225.5 | 56.0 | 583.3 | 6.2 |
| 213 | Græsted-Gilleleje | 108.9 | 130.3 | 222.8 | 55.3 | 557.3 | 4.1 |
| 215 | Helsingør | 107.9 | 128.6 | 219.8 | 54.6 | 541.9 | 3.8 |
| 217 | Helsingør | 349.1 | 418.1 | 714.6 | 177.4 | 1659.2 | 14.4 |
| 219 | Hillerød | 208.7 | 250.5 | 428.2 | 106.3 | 1093.7 | 8.1 |
| 221 | Hundested | 54.2 | 64.8 | 110.7 | 27.5 | 257.2 | 8.5 |
| 223 | Hørsholm | 146.4 | 175.4 | 299.0 | 73.7 | 794.5 | 23.7 |
| 225 | Jægerspris | 47.7 | 57.2 | 97.7 | 24.3 | 226.9 | 2.6 |
| 227 | Karlebo | 116.9 | 139.8 | 239.0 | 59.3 | 555.0 | 14.9 |
| 229 | Skibby | 36.2 | 43.1 | 73.7 | 18.3 | 171.3 | 2.3 |
| 231 | Skævinge | 31.8 | 37.1 | 63.4 | 15.7 | 148.0 | 2.4 |
| 233 | Silangerup | 47.7 | 57.3 | 97.9 | 24.3 | 227.2 | 5.4 |
| 235 | Stenløse | 79.2 | 95.1 | 162.2 | 40.1 | 476.6 | 6.2 |
| 237 | Ølstykke | 80.2 | 96.6 | 164.4 | 40.2 | 481.4 | 14.0 |
| 020 | Frederiksborg amtskommune | 2114.1 | 2531.8 | 4322.3 | 1069.7 | 10037.9 | 8.0 |

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|-------------------------|---|----------------------|--------------------------|--------------------------|--------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | | |
| 251 | Bramsnæs | 48.6 | 64.4 | 94.7 | 10.3 | 218.0 | 3.2 |
| 253 | Greve | 284.4 | 376.4 | 552.6 | 60.3 | 1273.7 | 23.1 |
| 255 | Gundløse | 77.6 | 102.2 | 151.6 | 17.9 | 349.3 | 5.8 |
| 257 | Hvalsø | 44.8 | 58.8 | 86.8 | 9.5 | 199.9 | 3.1 |
| 259 | Køge | 225.5 | 299.5 | 440.3 | 48.0 | 1013.3 | 9.3 |
| 261 | Løjt | 52.6 | 69.3 | 101.8 | 11.1 | 234.8 | 3.2 |
| 263 | Ramse | 54.1 | 72.1 | 106.0 | 11.6 | 243.8 | 3.8 |
| 265 | Roskilde | 306.5 | 406.5 | 597.6 | 65.2 | 1375.8 | 18.4 |
| 267 | Skovbo | 82.3 | 108.2 | 159.0 | 17.4 | 366.9 | 3.1 |
| 269 | Solrød | 119.7 | 158.1 | 232.5 | 25.4 | 535.7 | 15.1 |
| 271 | Vallo | 57.3 | 74.6 | 109.8 | 12.0 | 253.7 | 3.3 |
| 025 | Roskilde amtskommune | 1353.2 | 1790.0 | 2632.6 | 288.7 | 6064.5 | 7.5 |

Continued

Table 1 continued

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|------------------------------|---|----------------------|--------------------------|--------------------------|-----------------|--------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | Road traffic | | |
| 301 | Bjergsted | 59.2 | 35.0 | 72.5 | 8.4 | 20.5 | 195.5 | 1.4 |
| 303 | Dianalund | 55.5 | 33.2 | 68.7 | 7.9 | 13.0 | 178.2 | 2.7 |
| 305 | Dragsholm | 98.0 | 58.1 | 120.2 | 13.9 | 29.7 | 319.8 | 2.1 |
| 307 | Fuglebjerg | 49.5 | 29.4 | 60.4 | 7.0 | 19.8 | 166.1 | 1.2 |
| 309 | Gørlev | 46.5 | 27.6 | 57.2 | 6.6 | 14.1 | 152.0 | 1.7 |
| 311 | Høshøj | 50.3 | 29.2 | 60.3 | 7.0 | 22.3 | 169.0 | 1.3 |
| 313 | Haslev | 107.5 | 63.7 | 131.7 | 15.2 | 31.0 | 349.1 | 2.6 |
| 315 | Holbæk | 241.8 | 143.5 | 296.8 | 34.2 | 74.2 | 790.4 | 5.0 |
| 317 | Hvidebæk | 42.4 | 25.1 | 52.0 | 6.0 | 13.8 | 139.3 | 1.4 |
| 319 | Hong | 62.6 | 37.2 | 76.9 | 8.9 | 18.8 | 204.3 | 1.4 |
| 321 | Jernløse | 43.0 | 25.5 | 52.6 | 6.1 | 18.0 | 145.2 | 1.4 |
| 323 | Kalundborg | 151.4 | 89.8 | 185.7 | 21.4 | 23.4 | 471.6 | 3.6 |
| 325 | Korsør | 160.5 | 95.4 | 197.4 | 22.8 | 41.8 | 517.9 | 6.9 |
| 327 | Nykøbing-Rørvig | 53.2 | 31.7 | 65.6 | 7.6 | 10.5 | 168.6 | 4.2 |
| 329 | Ringsted | 223.0 | 132.2 | 273.5 | 31.5 | 88.9 | 749.2 | 2.5 |
| 331 | Skælskør | 86.2 | 51.2 | 105.9 | 12.2 | 22.7 | 278.1 | 1.6 |
| 333 | Slagelse | 265.2 | 157.6 | 325.9 | 37.6 | 75.5 | 861.7 | 4.5 |
| 335 | Soro | 110.9 | 66.0 | 136.6 | 15.7 | 51.2 | 380.5 | 2.6 |
| 337 | Stenlille | 39.5 | 23.2 | 48.0 | 5.5 | 13.7 | 129.9 | 1.4 |
| 339 | Svinninge | 48.8 | 28.9 | 59.7 | 6.9 | 17.4 | 161.7 | 1.9 |
| 341 | Tornved | 68.9 | 40.9 | 84.5 | 9.7 | 21.3 | 225.4 | 2.2 |
| 343 | Trundholm | 81.4 | 48.3 | 99.9 | 11.5 | 35.1 | 276.2 | 1.7 |
| 345 | Tollose | 71.4 | 42.7 | 87.9 | 10.1 | 26.7 | 238.9 | 1.9 |
| 030 | Vestsjællands amtskommune | 2216.6 | 1315.4 | 2719.9 | 313.5 | 703.2 | 7268.5 | 2.4 |

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|---------------------------|---|----------------------|--------------------------|--------------------------|-----------------|--------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | Road traffic | | |
| 351 | Fakse | 100.4 | 66.0 | 100.7 | 12.3 | 21.1 | 300.5 | 2.1 |
| 353 | Flådså | 63.8 | 41.8 | 63.8 | 7.8 | 32.3 | 209.5 | 1.6 |
| 355 | Holeby | 40.8 | 26.6 | 40.7 | 5.0 | 7.7 | 120.8 | 1.0 |
| 357 | Holmegård | 58.1 | 37.8 | 57.7 | 7.1 | 12.5 | 173.2 | 2.6 |
| 359 | Højreby | 39.2 | 25.6 | 39.1 | 4.8 | 14.8 | 123.6 | 1.0 |
| 361 | Langebæk | 53.0 | 34.6 | 52.8 | 6.5 | 15.3 | 162.1 | 1.6 |
| 363 | Maribo | 102.3 | 66.6 | 101.8 | 12.5 | 33.3 | 316.5 | 2.1 |
| 365 | Mon | 99.2 | 64.7 | 98.8 | 12.1 | 25.7 | 300.6 | 1.3 |
| 367 | Nakskov | 143.8 | 93.8 | 143.3 | 17.6 | 15.6 | 414.1 | 12.7 |
| 369 | Nykøbing Falster | 222.7 | 145.4 | 222.1 | 27.2 | 46.8 | 664.2 | 5.0 |
| 371 | Nysted | 51.1 | 33.0 | 50.4 | 6.2 | 12.2 | 152.9 | 1.1 |
| 373 | Næstved | 400.2 | 261.0 | 398.5 | 48.8 | 79.3 | 1187.8 | 5.9 |
| 375 | Nr. Alslev | 85.9 | 56.1 | 85.6 | 10.5 | 43.0 | 281.2 | 1.6 |
| 377 | Præsto | 61.7 | 40.2 | 61.3 | 7.5 | 23.9 | 194.6 | 1.8 |
| 379 | Ravnshøj | 58.4 | 38.0 | 58.1 | 7.1 | 10.0 | 171.6 | 0.9 |
| 381 | Rudbjerg | 34.3 | 22.3 | 34.0 | 4.2 | 6.6 | 101.3 | 0.7 |
| 383 | Rødby | 63.7 | 41.4 | 63.3 | 7.8 | 17.2 | 193.3 | 1.6 |
| 385 | Rønnede | 57.0 | 37.2 | 56.7 | 7.0 | 48.1 | 205.9 | 1.7 |
| 387 | Sakskøbing | 82.5 | 53.9 | 82.2 | 10.1 | 36.3 | 264.9 | 1.5 |
| 389 | Stevns | 93.2 | 61.0 | 93.1 | 11.4 | 15.3 | 274.1 | 1.7 |
| 391 | Stubbekøbing | 61.4 | 39.8 | 60.8 | 7.5 | 13.3 | 182.7 | 1.2 |
| 393 | Suså | 70.5 | 45.9 | 70.2 | 8.6 | 18.6 | 213.8 | 1.5 |
| 395 | Sydfalster | 59.3 | 38.9 | 59.4 | 7.3 | 16.1 | 181.0 | 1.6 |
| 397 | Vordingborg | 177.0 | 115.3 | 176.1 | 21.6 | 54.6 | 544.6 | 3.1 |
| 035 | Storstrøms amtskommune | 2279.5 | 1486.9 | 2270.5 | 278.1 | 619.7 | 6934.8 | 2.0 |

Continued

Table I continued

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|--------------------------|---|----------------------|--------------------------|--------------------------|--------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | | |
| 401 | Allinge-Gudhjem | 105.7 | 36.0 | 59.5 | 25.3 | 243.0 | 1.6 |
| 403 | Hasle | 87.0 | 29.5 | 48.7 | 20.7 | 201.0 | 1.8 |
| 405 | Nekso | 116.8 | 39.9 | 65.9 | 28.0 | 267.3 | 2.6 |
| 407 | Ronne | 196.2 | 67.1 | 110.9 | 47.1 | 442.7 | 15.3 |
| 409 | Åkirkeby | 89.7 | 30.4 | 50.1 | 21.3 | 212.6 | 1.1 |
| 411 | Christiansø | 1.5 | 0.0 | 0.0 | 0.0 | 1.6 | 3.9 |
| 040 | Bornholms amtskommune | 596.9 | 202.8 | 335.0 | 142.3 | 1368.1 | 2.3 |

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|---------------------|---|----------------------|--------------------------|--------------------------|---------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | | |
| 421 | Assens | 53.1 | 52.1 | 122.7 | 9.1 | 258.0 | 1.9 |
| 423 | Bogense | 30.3 | 29.7 | 69.9 | 5.2 | 146.4 | 1.4 |
| 425 | Broby | 31.7 | 31.1 | 73.2 | 5.4 | 155.0 | 1.6 |
| 427 | Egebjerg | 42.4 | 41.7 | 98.2 | 7.3 | 211.8 | 1.7 |
| 429 | Ejby | 48.6 | 47.7 | 112.4 | 8.4 | 260.5 | 1.6 |
| 431 | Fåborg | 86.0 | 84.2 | 198.5 | 14.8 | 420.5 | 1.9 |
| 433 | Glamsbjerg | 28.7 | 28.1 | 66.3 | 4.9 | 142.1 | 1.6 |
| 435 | Gudme | 30.1 | 29.5 | 69.4 | 5.2 | 144.8 | 1.2 |
| 437 | Hårby | 24.5 | 24.0 | 56.6 | 4.2 | 118.8 | 1.5 |
| 439 | Kerteminde | 51.1 | 49.9 | 117.6 | 8.7 | 247.9 | 1.7 |
| 441 | Langeskov | 29.4 | 29.0 | 68.2 | 5.1 | 151.0 | 3.5 |
| 443 | Marstal | 18.0 | 17.7 | 41.8 | 3.1 | 84.5 | 5.0 |
| 445 | Middelfart | 91.0 | 89.5 | 210.8 | 15.7 | 453.5 | 6.3 |
| 447 | Munkebo | 28.6 | 28.3 | 66.6 | 5.0 | 138.2 | 7.2 |
| 449 | Nyborg | 90.6 | 88.9 | 209.4 | 15.6 | 444.5 | 5.3 |
| 451 | Nr. Åby | 26.2 | 25.6 | 60.3 | 4.5 | 142.3 | 2.2 |
| 461 | Odense | 859.7 | 844.0 | 1988.5 | 148.0 | 4162.7 | 13.7 |
| 471 | Otterup | 54.6 | 53.5 | 126.2 | 9.4 | 263.6 | 1.6 |
| 473 | Ringe | 54.6 | 53.8 | 126.8 | 9.4 | 277.2 | 1.8 |
| 475 | Rudkøbing | 34.0 | 33.5 | 79.0 | 5.9 | 163.7 | 2.6 |
| 477 | Ryslinge | 34.8 | 34.1 | 80.3 | 6.0 | 173.8 | 2.1 |
| 479 | Svendborg | 201.0 | 197.2 | 464.7 | 34.6 | 955.7 | 5.5 |
| 481 | Sydlangeland | 23.8 | 23.3 | 54.9 | 4.1 | 117.2 | 1.0 |
| 483 | Sønderø | 55.0 | 53.8 | 126.8 | 9.4 | 267.5 | 1.5 |
| 485 | Tommerup | 36.2 | 35.5 | 83.6 | 6.2 | 178.5 | 2.4 |
| 487 | Tranekær | 19.2 | 18.7 | 44.1 | 3.3 | 95.1 | 0.9 |
| 489 | Ullerslev | 23.7 | 23.4 | 55.2 | 4.1 | 121.4 | 2.2 |
| 491 | Vissenbjerg | 29.2 | 28.7 | 67.7 | 5.0 | 168.6 | 3.6 |
| 493 | Ærøskøbing | 22.0 | 21.5 | 50.6 | 3.8 | 105.9 | 1.4 |
| 495 | Ørbæk | 32.6 | 31.8 | 74.8 | 5.6 | 163.3 | 1.2 |
| 497 | Årslev | 45.1 | 43.9 | 103.4 | 7.7 | 218.6 | 2.9 |
| 499 | Årup | 25.8 | 25.3 | 59.5 | 4.4 | 136.2 | 1.7 |
| 042 | Fyns amtskommune | 2261.8 | 2218.9 | 5228.1 | 389.1 | 11088.9 | 3.2 |

Continued

Table 1 continued

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|-------------------------------|---|-------------------|-----------------------|-----------------------|--------------|--------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | Road traffic | | |
| 501 | Augustenborg | 43.3 | 63.3 | 76.9 | 8.4 | 13.8 | 205.8 | 3.9 |
| 503 | Bov | 69.0 | 100.4 | 121.9 | 13.4 | 58.5 | 363.2 | 2.5 |
| 505 | Bredebro | 26.2 | 38.0 | 46.2 | 5.1 | 10.0 | 125.5 | 0.8 |
| 507 | Brøgger | 40.6 | 59.1 | 71.7 | 7.9 | 14.7 | 194.1 | 4.5 |
| 509 | Christiansfeld | 59.5 | 86.8 | 105.3 | 11.5 | 43.5 | 306.6 | 1.5 |
| 511 | Gram | 34.2 | 49.6 | 60.3 | 6.6 | 14.4 | 165.1 | 1.3 |
| 513 | Gråsten | 45.7 | 66.6 | 80.8 | 8.9 | 18.7 | 220.6 | 3.9 |
| 515 | Haderslev | 200.0 | 291.3 | 353.6 | 38.8 | 66.4 | 950.0 | 3.5 |
| 517 | Højer | 20.1 | 29.3 | 35.6 | 3.9 | 7.7 | 96.5 | 0.9 |
| 519 | Lundtoft | 40.9 | 59.6 | 72.3 | 7.9 | 33.8 | 214.6 | 1.6 |
| 521 | Løgumkloster | 46.2 | 67.1 | 81.4 | 8.9 | 19.7 | 223.2 | 1.1 |
| 523 | Nordborg | 98.3 | 143.0 | 173.6 | 19.0 | 25.6 | 459.6 | 3.7 |
| 525 | Nr. Rangstrup | 66.2 | 96.2 | 116.8 | 12.8 | 33.9 | 325.9 | 1.1 |
| 527 | Rødning | 72.3 | 105.3 | 127.9 | 14.0 | 33.0 | 352.6 | 1.3 |
| 529 | Rodekro | 73.0 | 106.2 | 128.9 | 14.1 | 52.2 | 374.4 | 1.9 |
| 531 | Skærbæk | 51.1 | 74.4 | 90.3 | 9.9 | 28.5 | 254.3 | 0.7 |
| 533 | Sundeved | 35.1 | 50.8 | 61.7 | 6.8 | 17.1 | 171.5 | 2.5 |
| 535 | Sydals | 44.4 | 64.4 | 78.2 | 8.6 | 13.3 | 208.9 | 2.2 |
| 537 | Sonderborg | 184.1 | 268.0 | 325.3 | 35.7 | 46.4 | 859.5 | 15.8 |
| 539 | Tinglev | 69.2 | 100.5 | 122.0 | 13.4 | 29.3 | 334.4 | 1.0 |
| 541 | Tønder | 83.4 | 121.5 | 147.5 | 16.2 | 35.3 | 404.0 | 2.2 |
| 543 | Vojens | 112.1 | 162.7 | 197.6 | 21.7 | 63.9 | 558.0 | 1.9 |
| 545 | Åbenrå | 141.4 | 206.0 | 250.0 | 27.4 | 63.9 | 688.7 | 5.4 |
| 050 | Sonderjyllands amtskommune | 1656.5 | 2410.2 | 2925.8 | 320.8 | 743.6 | 8056.7 | 2.1 |

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|---------------------|---|-------------------|-----------------------|-----------------------|--------------|--------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | Road traffic | | |
| 551 | Billund | 35.0 | 42.0 | 97.6 | 9.1 | 15.9 | 199.6 | 1.3 |
| 553 | Blåbjerg | 30.4 | 36.5 | 84.8 | 7.9 | 19.4 | 179.1 | 0.7 |
| 555 | Blåvandshuk | 18.1 | 22.1 | 51.3 | 4.8 | 11.2 | 107.4 | 0.5 |
| 557 | Bramming | 59.4 | 71.5 | 166.1 | 15.4 | 28.0 | 340.4 | 2.0 |
| 559 | Brørup | 28.7 | 34.5 | 80.2 | 7.5 | 15.2 | 166.1 | 1.6 |
| 561 | Esbjerg | 376.5 | 453.4 | 1053.5 | 98.0 | 126.6 | 2108.1 | 9.6 |
| 563 | Fanø | 14.8 | 17.9 | 41.5 | 3.9 | 2.8 | 80.8 | 1.5 |
| 565 | Grindsted | 79.4 | 95.4 | 221.7 | 20.6 | 46.0 | 463.2 | 1.2 |
| 567 | Helle | 38.6 | 46.2 | 107.3 | 10.0 | 22.6 | 224.7 | 0.8 |
| 569 | Holsted | 31.7 | 38.1 | 88.4 | 8.2 | 20.5 | 186.9 | 1.0 |
| 571 | Ribe | 83.2 | 100.1 | 232.5 | 21.6 | 49.0 | 486.4 | 1.4 |
| 573 | Varde | 87.2 | 105.0 | 244.1 | 22.7 | 47.0 | 506.0 | 2.0 |
| 575 | Vejen | 74.3 | 90.5 | 208.1 | 19.4 | 44.3 | 436.6 | 1.8 |
| 577 | Ølgod | 51.9 | 62.6 | 145.5 | 13.5 | 22.9 | 296.4 | 1.2 |
| 055 | Ribe amtskommune | 1009.3 | 1215.6 | 2822.7 | 262.6 | 471.4 | 5781.6 | 1.8 |

Continued

Table 1 continued

| No. | Municipality | | | Emission (tonne SO ₂ a ⁻¹) | | Road traffic | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|----------------------|------------------|-------------------|---|-----------------------|--------------|---------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | | | |
| 601 | Brødstrup | 52.9 | 114.8 | 140.8 | 18.2 | 22.1 | 348.9 | 1.7 |
| 603 | Borkop | 66.7 | 144.7 | 177.5 | 22.9 | 39.9 | 451.8 | 4.4 |
| 605 | Egtved | 88.2 | 190.6 | 233.8 | 30.2 | 46.4 | 589.2 | 1.8 |
| 607 | Fredericia | 288.4 | 624.1 | 765.4 | 99.0 | 91.6 | 1868.4 | 13.9 |
| 609 | Gedved | 60.1 | 130.7 | 160.3 | 20.7 | 27.8 | 399.7 | 2.6 |
| 611 | Giv | 85.5 | 184.6 | 226.3 | 29.3 | 40.6 | 566.3 | 1.4 |
| 613 | Hedensted | 90.7 | 196.4 | 240.9 | 31.1 | 37.4 | 596.5 | 4.3 |
| 615 | Horsens | 343.4 | 742.9 | 911.1 | 117.8 | 97.3 | 2212.6 | 11.7 |
| 617 | Jelling | 30.8 | 67.4 | 82.7 | 10.7 | 9.8 | 201.4 | 2.3 |
| 619 | Juelsminde | 92.1 | 199.6 | 244.8 | 31.6 | 32.4 | 600.5 | 2.5 |
| 621 | Kolding | 358.0 | 774.4 | 949.8 | 122.8 | 143.4 | 2348.4 | 9.8 |
| 623 | Lunderskov | 30.1 | 64.6 | 79.9 | 10.3 | 12.4 | 197.4 | 2.1 |
| 625 | Nr. Snede | 45.9 | 99.3 | 121.7 | 15.7 | 36.4 | 319.0 | 1.3 |
| 627 | Torring-Uldum | 72.7 | 156.7 | 192.1 | 24.8 | 50.3 | 496.6 | 2.6 |
| 629 | Vamdrup | 42.8 | 92.4 | 113.3 | 14.6 | 18.5 | 281.6 | 2.8 |
| 631 | Vejle | 318.3 | 690.0 | 846.2 | 109.4 | 122.0 | 2086.0 | 14.5 |
| 060 | Vejle amtskommune | 2066.8 | 4473.2 | 5486.7 | 709.3 | 828.3 | 13564.2 | 4.5 |

| No. | Municipality | | | Emission (tonne SO ₂ a ⁻¹) | | Road traffic | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|---------------------------|------------------|-------------------|---|-----------------------|--------------|---------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | | | |
| 651 | Avlum-Haderup | 41.9 | 146.1 | 105.1 | 8.3 | 21.2 | 322.6 | 1.3 |
| 653 | Brande | 53.3 | 188.6 | 135.6 | 10.6 | 19.4 | 407.5 | 2.2 |
| 655 | Egvad | 60.2 | 212.6 | 152.8 | 12.0 | 32.8 | 470.3 | 1.3 |
| 657 | Herning | 352.1 | 1244.8 | 894.6 | 70.1 | 142.2 | 2703.7 | 5.0 |
| 659 | Holmsland | 33.3 | 117.4 | 84.4 | 6.6 | 22.5 | 264.1 | 2.8 |
| 661 | Holstebro | 239.7 | 847.5 | 609.0 | 47.7 | 78.3 | 1822.2 | 5.2 |
| 663 | Ikast | 137.0 | 484.2 | 348.0 | 27.3 | 59.0 | 1055.5 | 3.6 |
| 665 | Lemvig | 120.3 | 425.3 | 305.6 | 24.0 | 36.3 | 911.4 | 2.0 |
| 667 | Ringkøbing | 106.4 | 376.8 | 270.8 | 21.2 | 40.9 | 816.2 | 2.0 |
| 669 | Skjern | 78.9 | 279.1 | 200.6 | 15.7 | 27.3 | 601.6 | 1.8 |
| 671 | Struer | 119.3 | 422.0 | 303.3 | 23.8 | 34.4 | 902.8 | 5.2 |
| 673 | Thyborøn-Harboør | 33.1 | 117.1 | 84.1 | 6.6 | 10.0 | 250.9 | 6.0 |
| 675 | Thyholm | 24.4 | 85.0 | 61.3 | 4.9 | 11.4 | 187.0 | 2.5 |
| 677 | Trehøje | 57.8 | 204.1 | 146.7 | 11.5 | 18.1 | 438.2 | 1.5 |
| 679 | Ulfborg-Vemb | 44.4 | 156.9 | 112.7 | 8.8 | 15.4 | 338.3 | 1.5 |
| 681 | Videbæk | 74.9 | 264.9 | 190.4 | 14.9 | 29.2 | 574.4 | 2.0 |
| 683 | Vinderup | 51.2 | 179.9 | 129.4 | 10.2 | 26.4 | 397.1 | 1.8 |
| 685 | Åskov | 42.6 | 150.6 | 108.2 | 8.5 | 20.9 | 330.8 | 1.4 |
| 065 | Ringkøbing amtskommune | 1670.9 | 5902.8 | 4242.5 | 332.9 | 645.7 | 12794.8 | 2.6 |

Continued

Table I continued

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | Road traffic | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|----------------------|---|-------------------|-----------------------|-----------------------|--------------|---------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | | | |
| 701 | Ebeltoft | 63.4 | 155.5 | 140.2 | 14.4 | 31.9 | 405.2 | 1.5 |
| 703 | Galten | 48.7 | 118.8 | 107.1 | 11.0 | 19.4 | 305.0 | 4.2 |
| 705 | Gjern | 36.1 | 88.1 | 79.4 | 8.1 | 21.4 | 233.2 | 1.6 |
| 707 | Grenå | 92.4 | 226.4 | 204.1 | 20.9 | 29.1 | 572.9 | 2.9 |
| 709 | Hadsten | 53.8 | 131.3 | 118.4 | 12.1 | 34.4 | 349.9 | 2.5 |
| 711 | Hammel | 49.2 | 120.5 | 108.6 | 11.1 | 29.4 | 318.8 | 2.2 |
| 713 | Hinnerup | 49.3 | 120.8 | 108.9 | 11.2 | 17.4 | 307.6 | 4.0 |
| 715 | Horning | 37.0 | 90.9 | 82.0 | 8.4 | 24.1 | 242.4 | 3.6 |
| 717 | Langå | 41.3 | 100.7 | 90.6 | 9.4 | 17.7 | 259.7 | 2.0 |
| 719 | Mariager | 40.4 | 99.2 | 89.4 | 9.2 | 17.9 | 256.1 | 1.3 |
| 721 | Midtdjurs | 37.4 | 91.4 | 82.4 | 8.4 | 17.1 | 236.7 | 1.3 |
| 723 | Nørhald | 43.4 | 106.2 | 95.8 | 9.8 | 18.7 | 273.9 | 1.4 |
| 725 | Nr. Djurs | 38.2 | 93.8 | 84.6 | 8.7 | 15.8 | 241.1 | 1.0 |
| 727 | Odder | 91.3 | 223.6 | 201.6 | 20.7 | 32.9 | 570.1 | 2.5 |
| 729 | Purhus | 44.5 | 108.0 | 97.3 | 10.1 | 22.9 | 282.8 | 1.7 |
| 731 | Randers | 304.5 | 747.1 | 673.5 | 69.0 | 119.9 | 1914.1 | 12.5 |
| 733 | Rosenholm | 47.0 | 115.3 | 104.0 | 10.7 | 32.0 | 309.0 | 2.2 |
| 735 | Rougso | 40.2 | 98.5 | 88.8 | 9.1 | 13.3 | 250.0 | 1.1 |
| 737 | Ry | 48.2 | 118.3 | 106.7 | 10.9 | 26.6 | 310.8 | 2.0 |
| 739 | Ronde | 29.5 | 72.5 | 65.3 | 6.7 | 25.7 | 199.7 | 2.0 |
| 741 | Samsø | 22.1 | 54.1 | 48.8 | 5.0 | 6.6 | 136.6 | 1.2 |
| 743 | Silkeborg | 238.9 | 586.6 | 528.8 | 54.2 | 86.1 | 1494.6 | 5.9 |
| 745 | Skanderborg | 98.3 | 240.5 | 216.8 | 22.2 | 68.4 | 646.3 | 4.5 |
| 747 | Sonderhald | 40.6 | 99.5 | 89.7 | 9.2 | 30.8 | 269.8 | 2.0 |
| 749 | Them | 31.5 | 75.8 | 68.3 | 7.0 | 25.1 | 207.8 | 1.0 |
| 751 | Århus | 1286.2 | 3153.6 | 2843.2 | 291.3 | 412.4 | 7986.7 | 17.0 |
| 070 | Århus amtskommune | 2953.5 | 7237.1 | 6524.4 | 668.8 | 1197.1 | 18580.9 | 4.1 |

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|-----------------------|---|----------------------|--------------------------|--------------------------|-----------------|--------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | Road traffic | | |
| 761 | Bjerringbro | 102.6 | 175.2 | 144.6 | 24.5 | 30.5 | 477.4 | 2.3 |
| 763 | Fjends | 64.2 | 110.1 | 90.7 | 15.3 | 21.3 | 301.6 | 1.2 |
| 765 | Hanstholm | 47.5 | 80.6 | 66.5 | 11.3 | 12.6 | 218.5 | 1.0 |
| 767 | Hvorslev | 51.0 | 87.3 | 72.3 | 12.1 | 11.1 | 233.8 | 1.8 |
| 769 | Karup | 53.4 | 91.7 | 75.5 | 12.7 | 20.1 | 253.3 | 1.6 |
| 771 | Kjellerup | 105.6 | 180.5 | 149.0 | 25.3 | 47.2 | 507.7 | 2.0 |
| 773 | Morsø | 190.2 | 323.9 | 267.3 | 45.3 | 42.5 | 869.2 | 2.4 |
| 775 | Moldrup | 58.3 | 98.7 | 81.5 | 15.4 | 25.3 | 279.2 | 1.3 |
| 777 | Sallingsund | 49.7 | 84.8 | 69.9 | 11.9 | 16.4 | 232.7 | 2.3 |
| 779 | Skive | 212.4 | 361.8 | 298.5 | 50.6 | 53.3 | 976.6 | 4.2 |
| 781 | Spottrup | 62.5 | 106.5 | 87.9 | 14.9 | 19.1 | 290.9 | 1.5 |
| 783 | Sundsøre | 54.7 | 93.2 | 76.9 | 13.1 | 11.6 | 249.5 | 1.5 |
| 785 | Sydtby | 97.9 | 167.6 | 138.1 | 23.3 | 27.5 | 454.3 | 1.4 |
| 787 | Thisted | 235.1 | 400.8 | 330.8 | 56.1 | 72.8 | 1095.6 | 1.9 |
| 789 | Tjele | 65.3 | 111.0 | 91.6 | 15.5 | 31.3 | 314.8 | 1.2 |
| 791 | Viborg | 312.7 | 533.1 | 439.9 | 74.6 | 91.2 | 1451.5 | 4.6 |
| 793 | Ålestrup | 59.5 | 101.8 | 84.0 | 15.6 | 21.3 | 282.3 | 1.6 |
| 076 | Viborg amtskommune | 1822.7 | 3108.8 | 2564.9 | 437.6 | 554.9 | 8488.9 | 2.1 |

Continued

Table 1 continued

| No. | Municipality | Emission (tonne SO ₂ a ⁻¹) | | | | | Total | Emission density tonne SO ₂ km ⁻² a ⁻¹ |
|-----|-----------------------------|---|----------------------|--------------------------|--------------------------|-----------------|---------|--|
| | | Domestic heating | Energy generation | Industrial combustion | Industrial production | Road traffic | | |
| 801 | Arden | 50.4 | 94.1 | 80.5 | 140.4 | 30.5 | 395.9 | 1.7 |
| 803 | Brovst | 53.2 | 99.5 | 85.1 | 148.5 | 18.0 | 404.3 | 1.8 |
| 805 | Brønderslev | 125.6 | 234.4 | 200.5 | 349.8 | 43.7 | 954.0 | 3.0 |
| 807 | Dronninglund | 94.5 | 176.6 | 151.0 | 263.5 | 45.8 | 731.4 | 2.3 |
| 809 | Farso | 49.5 | 92.4 | 79.1 | 138.0 | 19.0 | 378.0 | 1.9 |
| 811 | Fjerritslev | 51.4 | 95.9 | 82.0 | 143.1 | 23.2 | 395.6 | 1.3 |
| 813 | Frederikshavn | 220.2 | 411.4 | 351.9 | 614.0 | 61.9 | 1659.4 | 9.3 |
| 815 | Hadsund | 64.9 | 121.2 | 103.7 | 181.0 | 24.2 | 495.0 | 2.9 |
| 817 | Hals | 66.3 | 123.7 | 105.8 | 184.7 | 18.9 | 499.4 | 2.6 |
| 819 | Hirtshals | 90.1 | 168.2 | 143.8 | 251.0 | 29.5 | 682.5 | 3.5 |
| 821 | Hjørring | 213.0 | 398.6 | 340.9 | 594.9 | 68.3 | 1615.7 | 5.2 |
| 823 | Hobro | 86.8 | 162.6 | 139.1 | 239.8 | 42.5 | 670.9 | 4.1 |
| 825 | Læso | 15.9 | 29.7 | 25.4 | 44.3 | 4.8 | 119.9 | 1.1 |
| 827 | Logstor | 66.3 | 124.2 | 106.2 | 185.4 | 22.2 | 504.3 | 2.3 |
| 829 | Lokken-Vrå | 54.9 | 102.7 | 87.8 | 153.2 | 19.3 | 417.8 | 2.3 |
| 831 | Nibe | 46.2 | 86.1 | 73.7 | 128.5 | 13.9 | 348.4 | 1.9 |
| 833 | Norager | 34.3 | 64.0 | 54.7 | 94.1 | 21.2 | 268.3 | 1.6 |
| 835 | Pandrup | 64.4 | 120.5 | 103.1 | 179.8 | 25.7 | 493.4 | 2.6 |
| 837 | Sejfflod | 56.1 | 104.2 | 89.1 | 155.5 | 15.1 | 419.9 | 2.0 |
| 839 | Sindal | 59.6 | 111.4 | 95.3 | 166.2 | 22.6 | 455.0 | 1.9 |
| 841 | Skagen | 86.0 | 160.8 | 137.6 | 240.0 | 27.2 | 651.7 | 4.6 |
| 843 | Skorping | 58.9 | 110.3 | 94.3 | 164.6 | 21.7 | 449.8 | 1.9 |
| 845 | Stovring | 74.1 | 138.3 | 118.3 | 206.4 | 40.6 | 577.8 | 2.6 |
| 847 | Sæby | 112.2 | 209.8 | 179.5 | 313.2 | 48.5 | 863.2 | 2.7 |
| 849 | Åbybro | 68.4 | 127.4 | 109.0 | 190.2 | 26.9 | 521.9 | 3.1 |
| 851 | Ålborg | 956.6 | 1788.9 | 1530.2 | 2670.1 | 287.8 | 7233.6 | 12.9 |
| 861 | Års | 77.3 | 144.4 | 123.5 | 215.5 | 25.2 | 585.9 | 2.6 |
| 080 | Nordjyllands amtskommune | 2997.0 | 5601.1 | 4791.0 | 8355.8 | 1048.1 | 22793.0 | 3.7 |

Table 2. *SO₂ emissions from large point sources for the counties in Denmark.*

| No. | Municipality | Emission in tonne SO ₂ a ⁻¹ |
|-------|----------------------------|--|
| 015 | Københavns amtskommune | 16071. |
| 020 | Frederiksborg amtskommune | 4028. |
| 030 | Vestsjællands amtskommune | 47795. |
| 035 | Storstrøms amtskommune | 1711. |
| 042 | Fyns amtskommune | 39952. |
| 050 | Sønderjyllands amtskommune | 19702. |
| 055 | Ribe amtskommune | 15399. |
| 060 | Vejle amtskommune | 9184. |
| 070 | Århus amtskommune | 3963. |
| 080 | Nordjyllands amtskommune | 8253. |
| Total | | 166058. |

Table 3. *Estimated SO₂ emissions from maritime vessels.*

| | Tonne SO ₂ a ⁻¹ |
|---------------------------------|---------------------------------------|
| International freighter traffic | 15157. |
| Main national ferry services | 2316. |
| Total | 17473. |

Table 4. *Total Danish SO₂ emissions.*

| Source | Tonne SO ₂ a ⁻¹ | % |
|-----------------------|---------------------------------------|--------|
| Domestic heating | 32803. | 9.35 |
| Energy generation | 46969. | 13.38 |
| Industrial combustion | 61373. | 17.49 |
| Industrial production | 15200. | 4.33 |
| Road traffic | 11119. | 3.17 |
| Maritime vessels | 17473. | 4.98 |
| Large point sources | 166058. | 47.31 |
| Total | 350995. | 100.01 |

The difference between the summary of 'road traffic' in the Table 1 and the figure given here in Table 4, arise from rounding off and from the gridding of the emissions from roads. Where some km² with emissions, do not exist in the land-use registration and therefore cannot be assigned to a municipality. This is e.g. caused by the fact that there is traffic on bridges between islands and these bridges are in the land-use survey registered as sea.

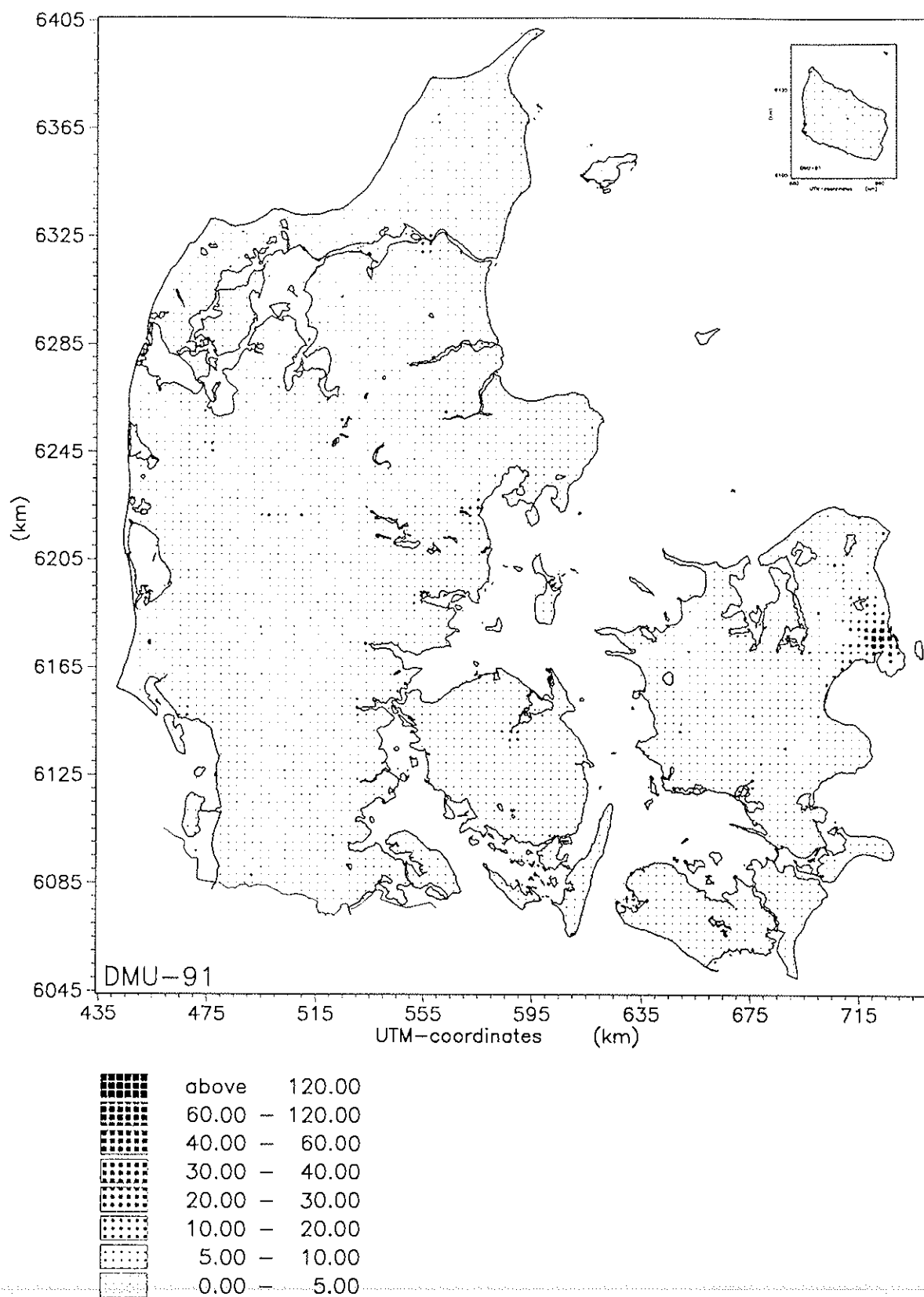


Figure 1. SO₂ emissions density from domestic heating (tonne SO₂ km⁻² a⁻¹).
(Note that the scale is not linear).

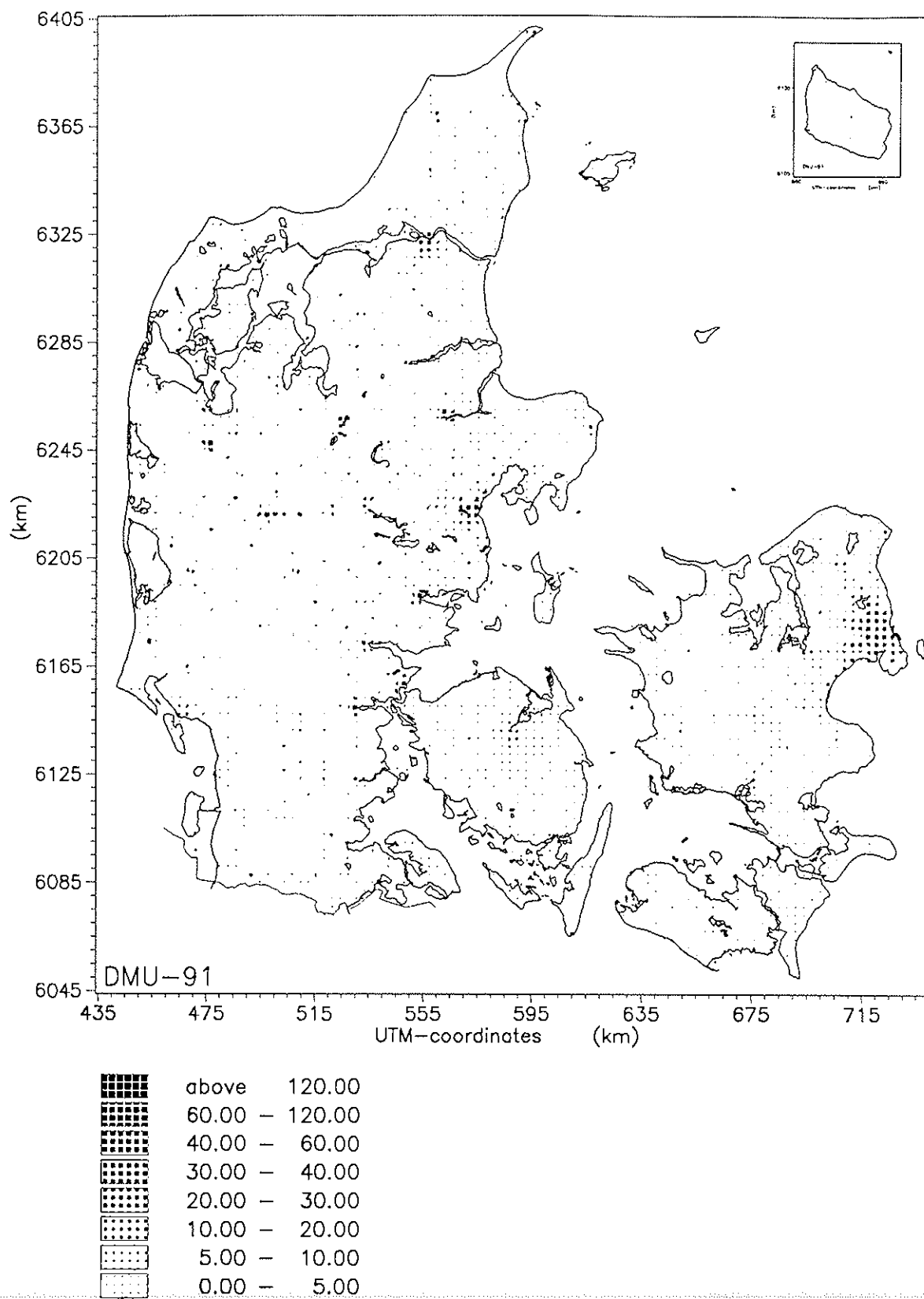


Figure 2. SO_2 emissions density from energy generation ($\text{tonne SO}_2 \text{ km}^{-2} \text{ a}^{-1}$).
(Note that the scale is not linear).

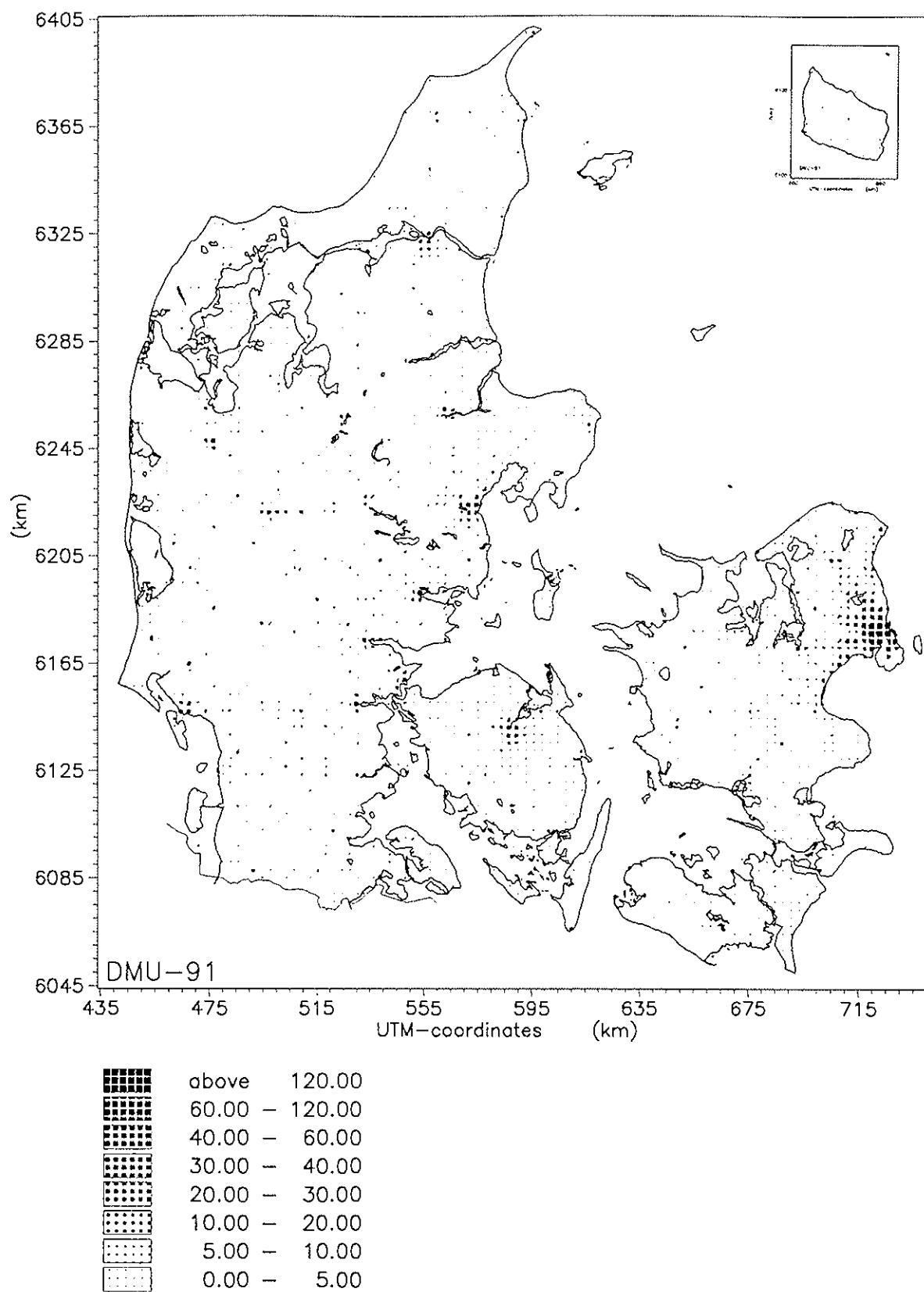


Figure 3. SO_2 emissions density from industrial combustion ($\text{tonne SO}_2 \text{ km}^{-2} \text{ a}^{-1}$).
(Note that the scale is not linear).

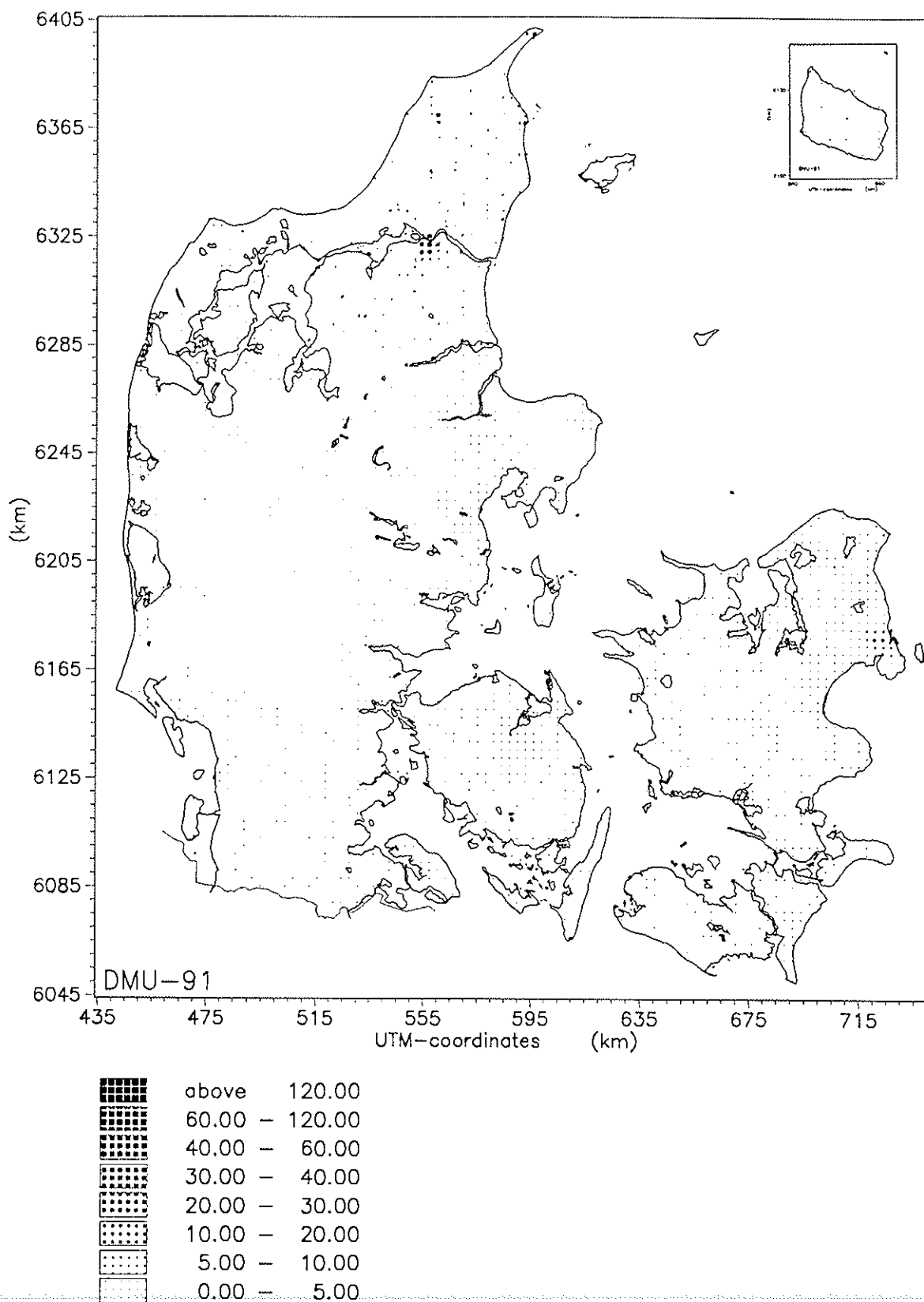


Figure 4. SO_2 emissions density from industrial production ($\text{tonne SO}_2 \text{ km}^{-2} \text{ a}^{-1}$).
(Note that the scale is not linear).

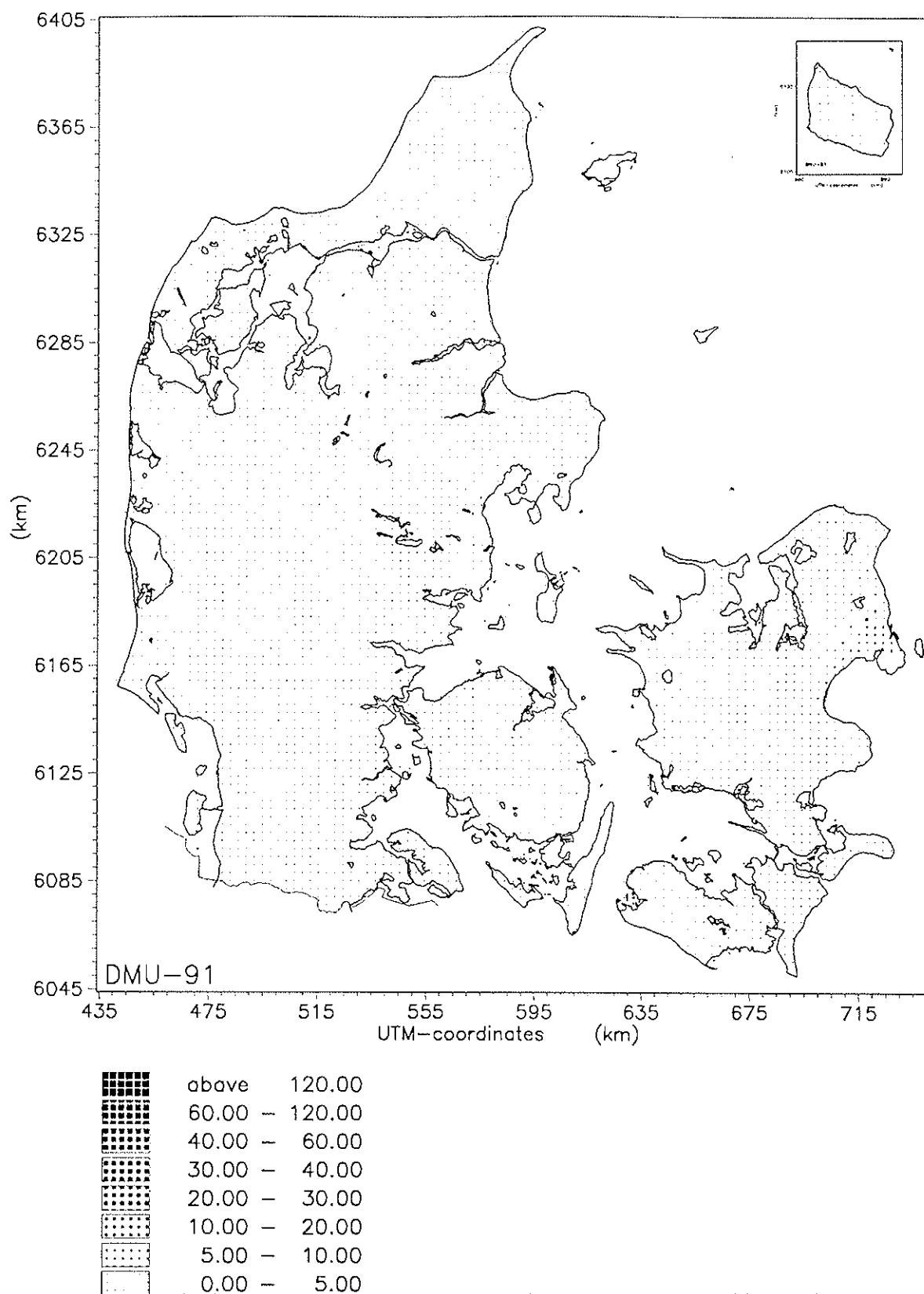


Figure 5. SO_2 emissions density from road traffic ($\text{tonne SO}_2 \text{ km}^{-2} \text{ a}^{-1}$).
(Note that the scale is not linear).

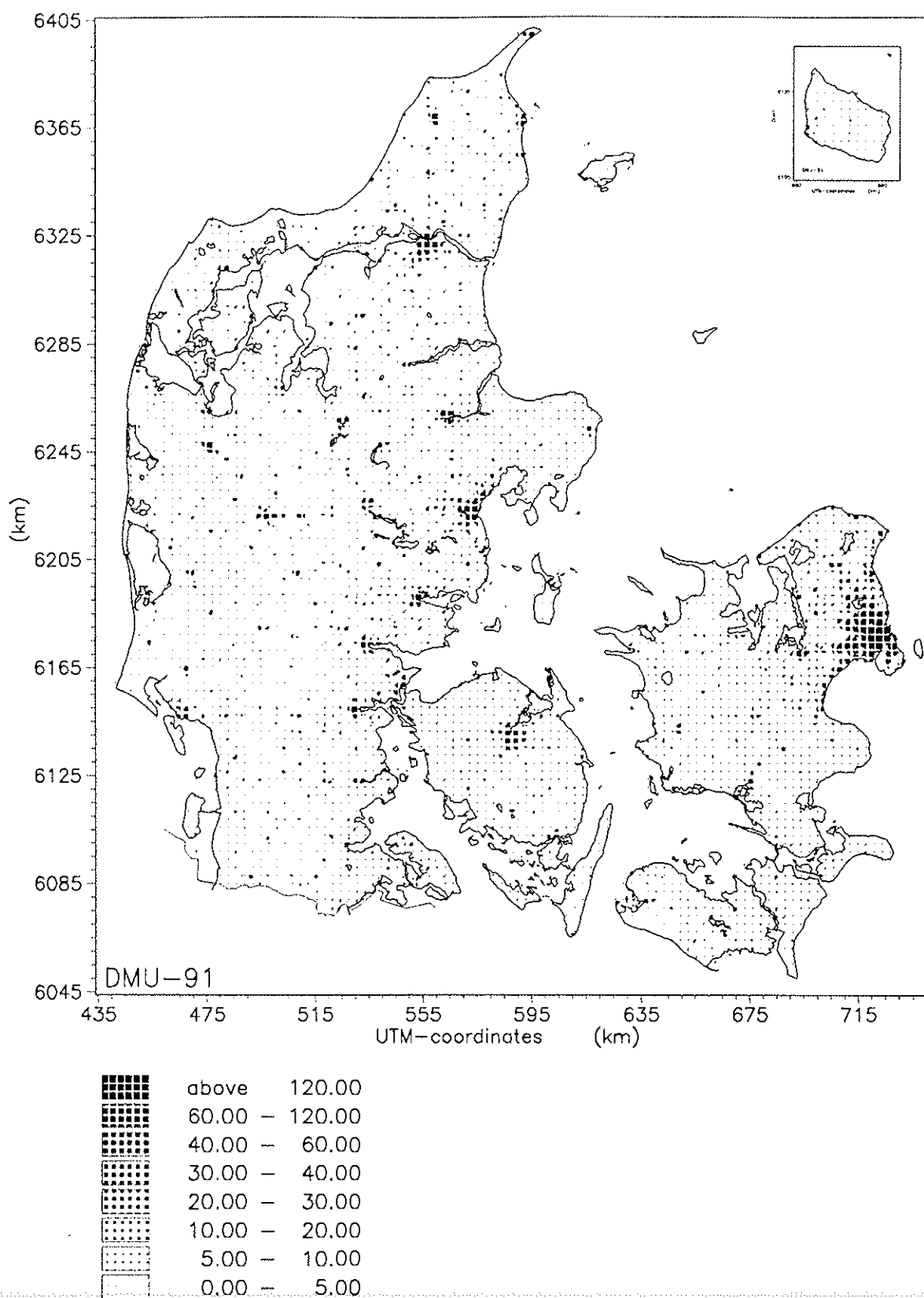


Figure 6. Total SO_2 emissions density from area sources ($\text{tonne SO}_2 \text{ km}^{-2} \text{ a}^{-1}$).
(Note that the scale is not linear).

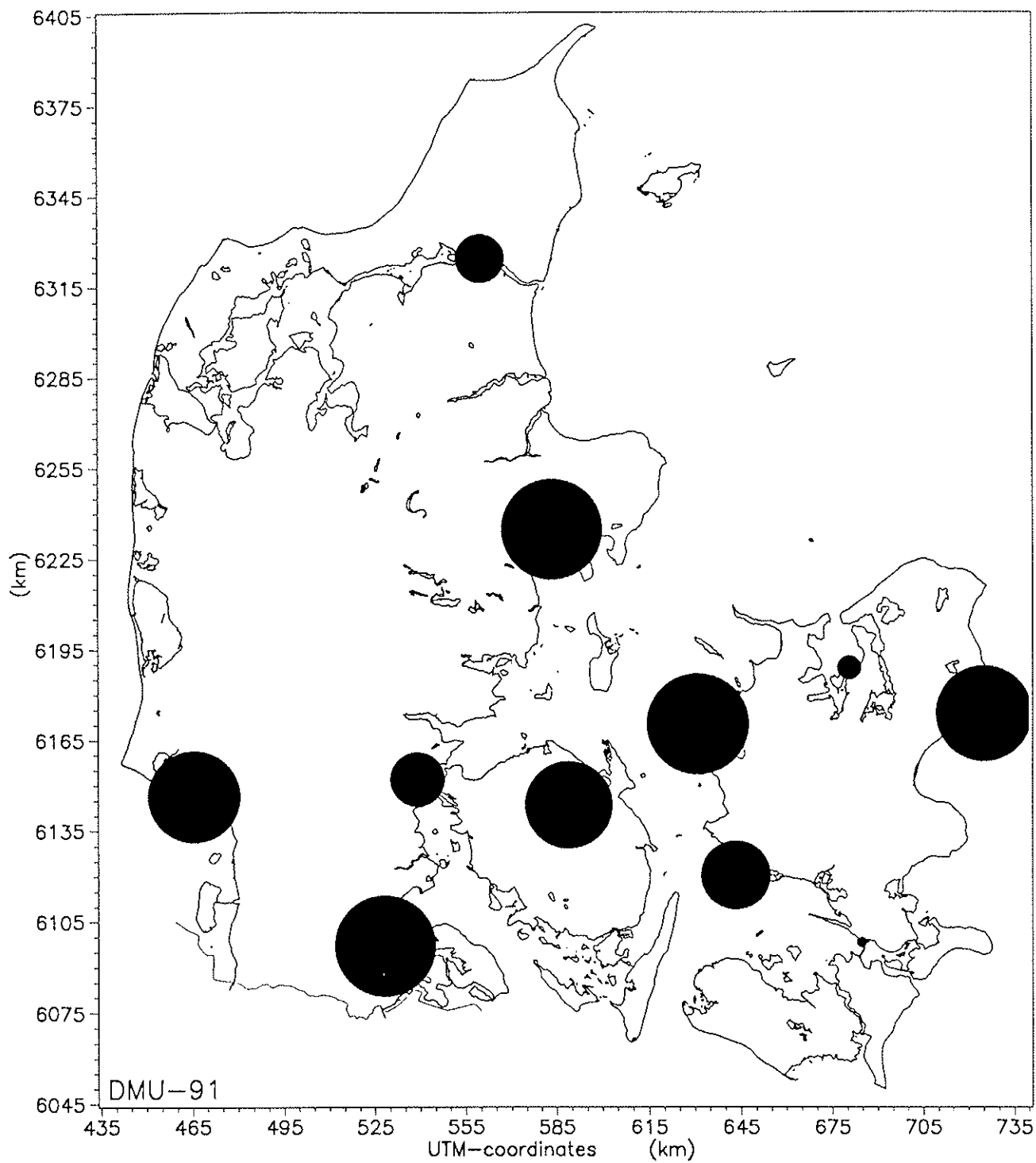


Figure 7. SO₂ emissions from major Danish point sources. The diameter of a circle shows the relative magnitude of the source. Sources near each other have been clustered for clarity.

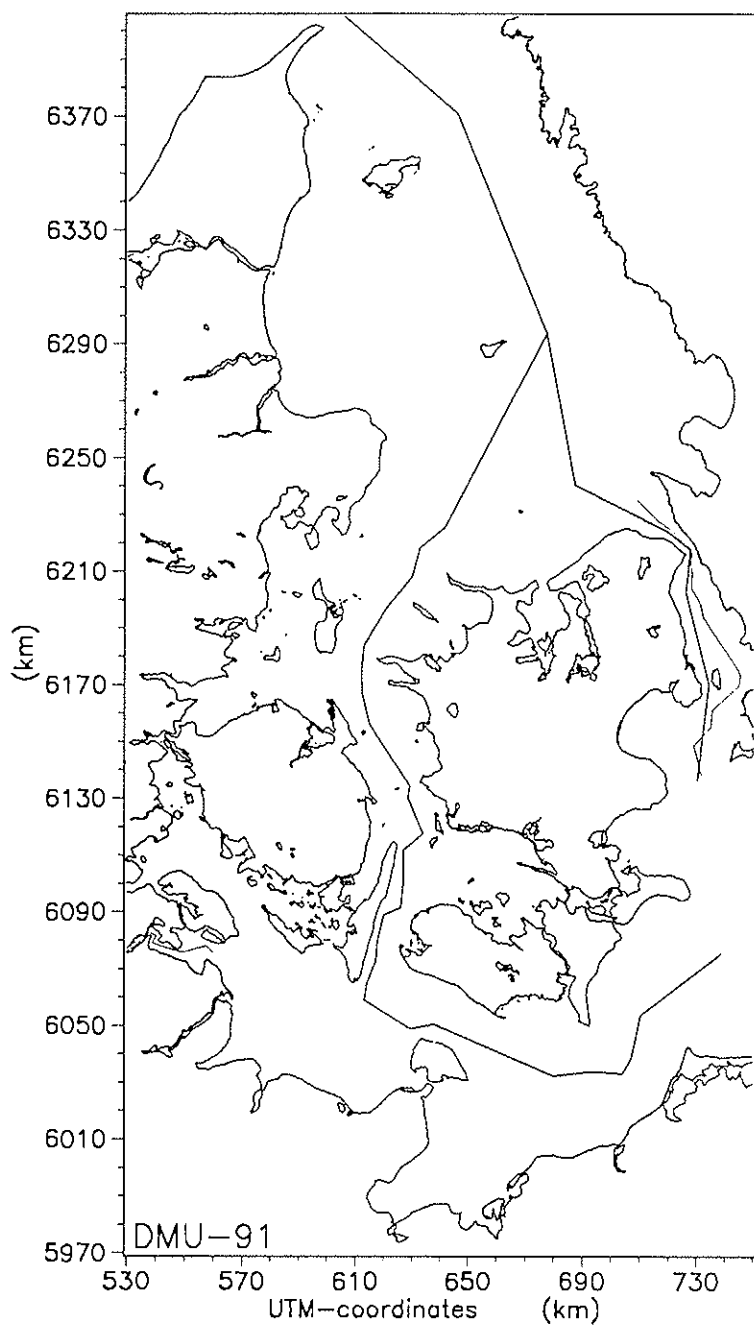


Figure 8. Main freighter routes through Danish waters.

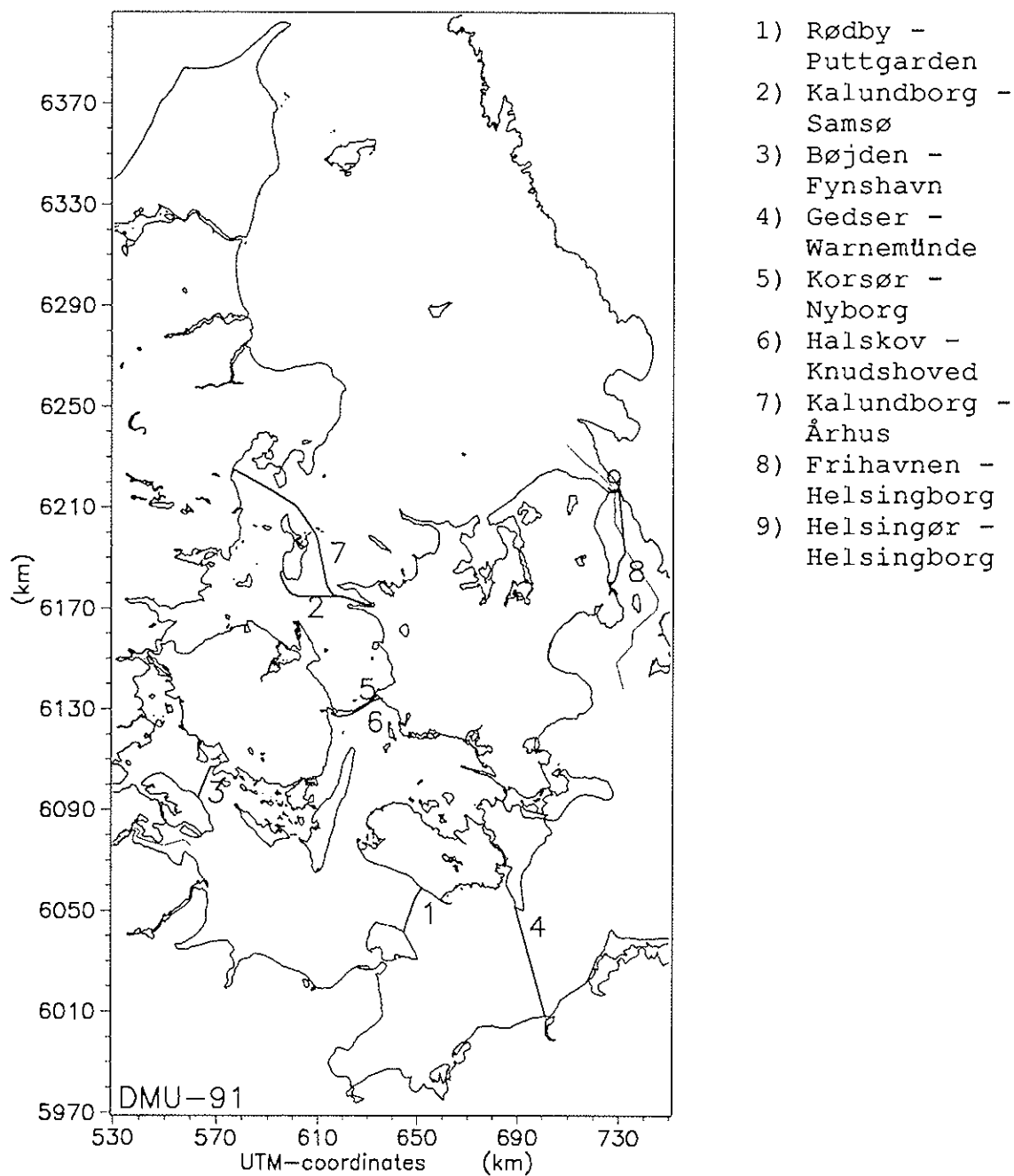


Figure 9. Main ferry services run by DSB.

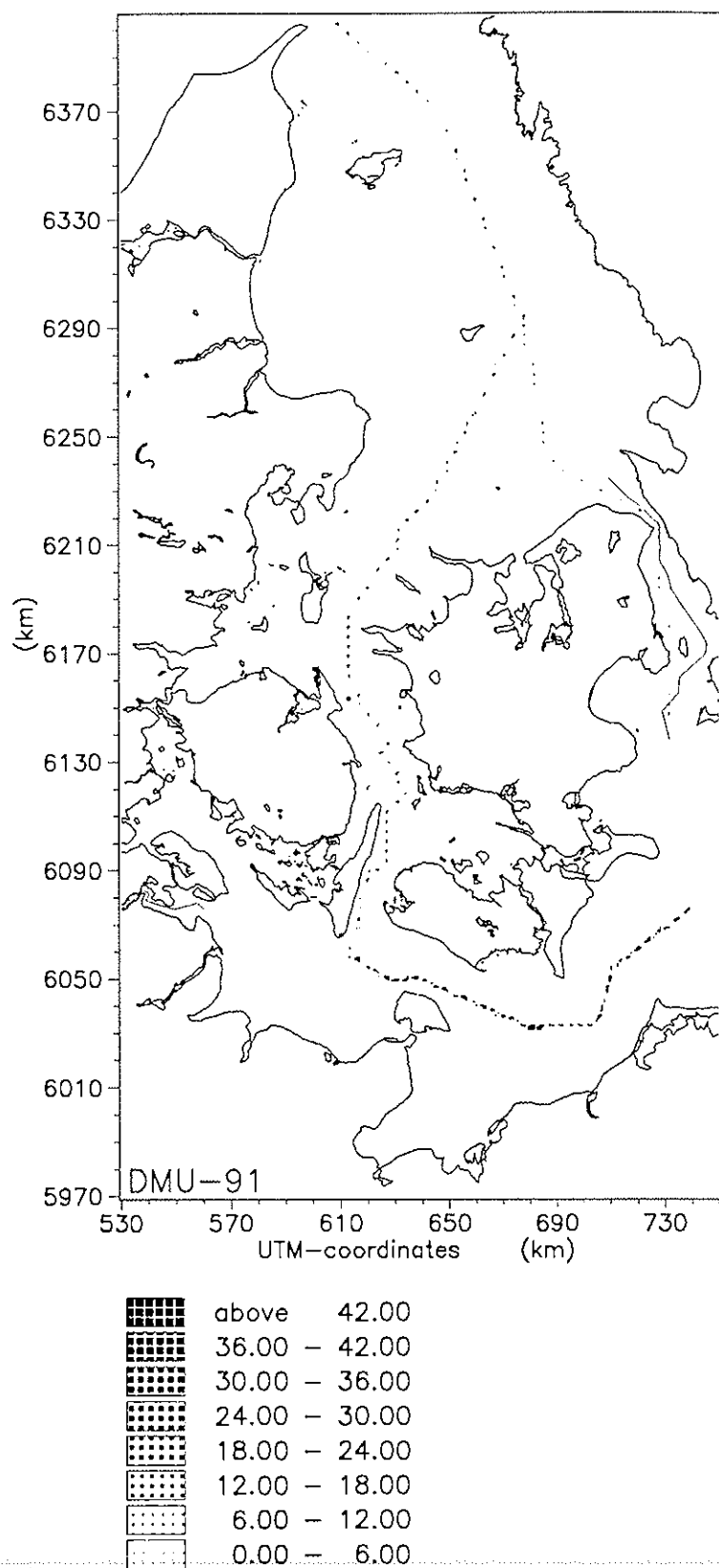


Figure 10. SO_2 emissions density from international freight traffic ($\text{tonne SO}_2 \text{ km}^{-2} \text{ a}^{-1}$).
(Note that the scale is not linear).

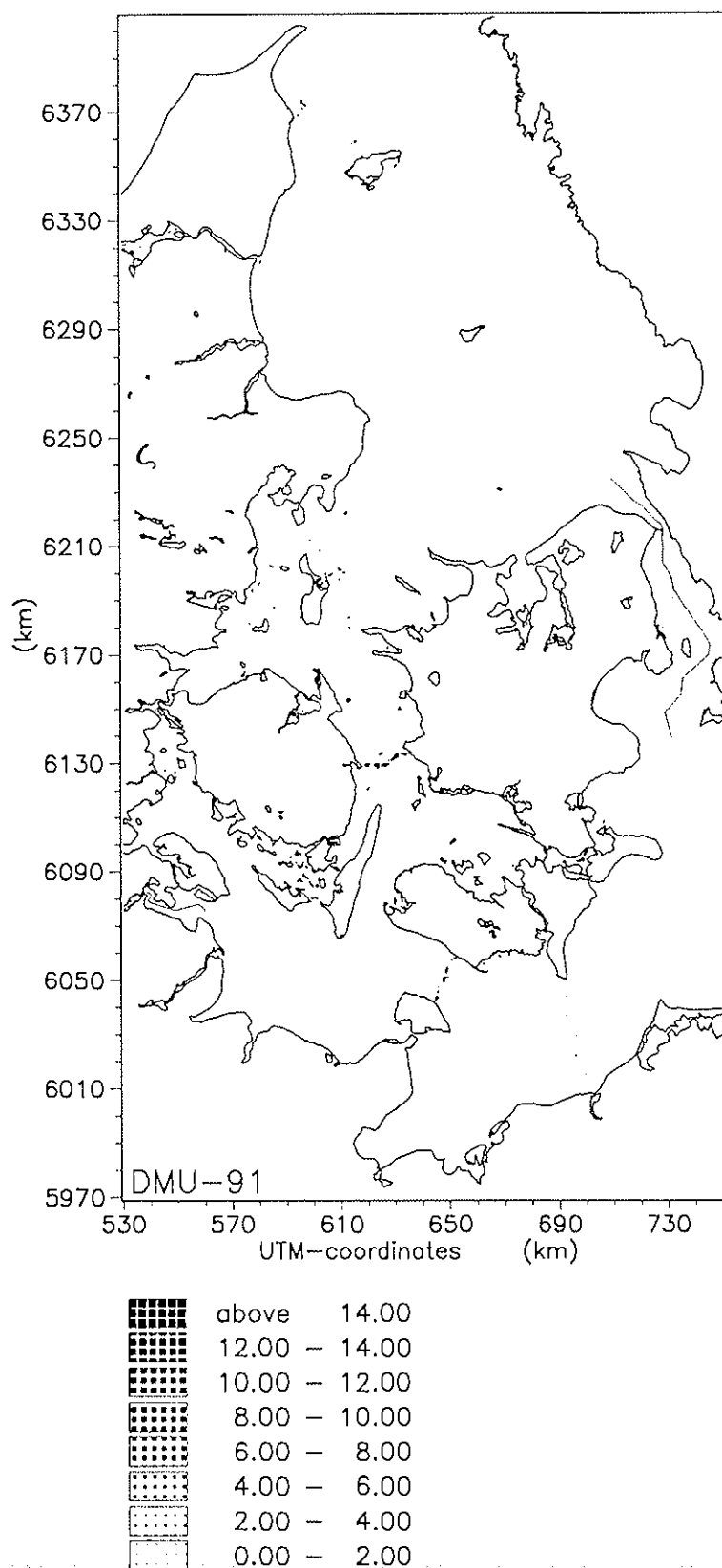
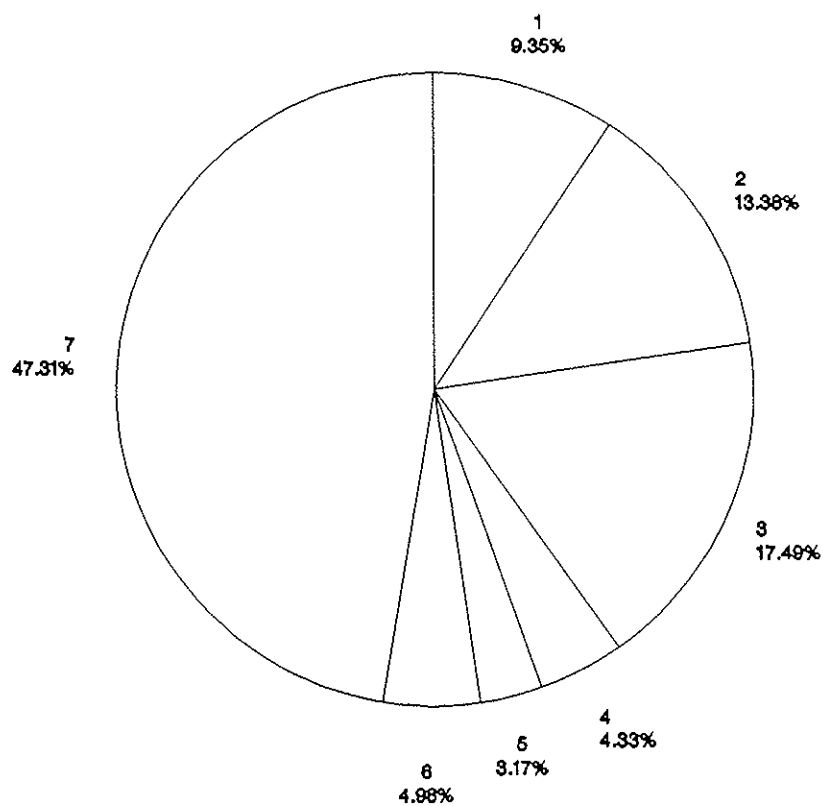


Figure 11. SO₂ emissions density from main ferry services (tonne SO₂ km⁻² a⁻¹).
(Note that the scale is not linear).



- 1 = Domestical heating
- 2 = Energy generation
- 3 = Industrial combustion
- 4 = Industrial production
- 5 = Road traffic
- 6 = Maritime vessels
- 7 = Point sources

Figure 12. Relative contributions of the different source categories to the total SO_2 emission.

Appendix A

Format of output files

In the following the format of the output files are given as read and written by fortran.

The file, SO2-AREA, with emissions from area sources has the format:

i3, i5, 6 (1x, f10.5)

with the collums:

X and Y coordinate (UTM zone 32)
Emission (tonne SO₂ a⁻¹) from:
domestic heating,
energy generation,
combustion in industry,
industrial production,
road traffic and
total emission.

The file, SO2-POINT, with emissions from point sources has the format:

a20, 1x, i2, i7, i8, 2i4, i8, i6

with the collumns:

Name of point source
X and Y coordinate (global longitude and latitude)
Height (m) of chimney
Temperature (°C) of flue gas
Volume (1000 m³ a⁻¹)
Emission (tonne SO₂ a⁻¹).

The files, SO2-FREIGHTER and SO2-FERRY, with emissions from freighter and ferry traffic have the format:

i4, i5, f15.4

with the collumns:

X and Y coordinates (UTM zone 32)
Emission (tonne SO₂ a⁻¹).

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Abstract (Max. 2000 characters)

The Danish SO₂ emissions from domestic heating, energy generation, industry, road traffic, point sources and maritime vessels have been distributed on a 1 × 1 km² grid and on municipalities.

The total SO₂ emission is calculated to 351 Ktonne SO₂ a⁻¹. This report describes the distribution, of the emissions from the different categories on the grid and municipalities.

Descriptors INIS/EDB

COMPILED DATA; DENMARK; EMISSION;
FOSSIL-FUEL POWER PLANTS; HEATING;
INDUSTRY; INVENTORIES; POINT POLLUTION
SOURCES; POLLUTION SOURCES; POWER
GENERATION; REGIONAL ANALYSIS;
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SHIPS; SPATIAL DISTRIBUTION; STATISTICAL
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